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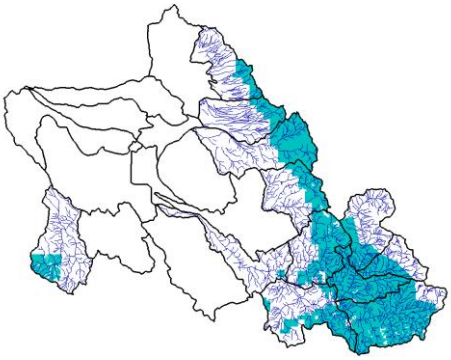

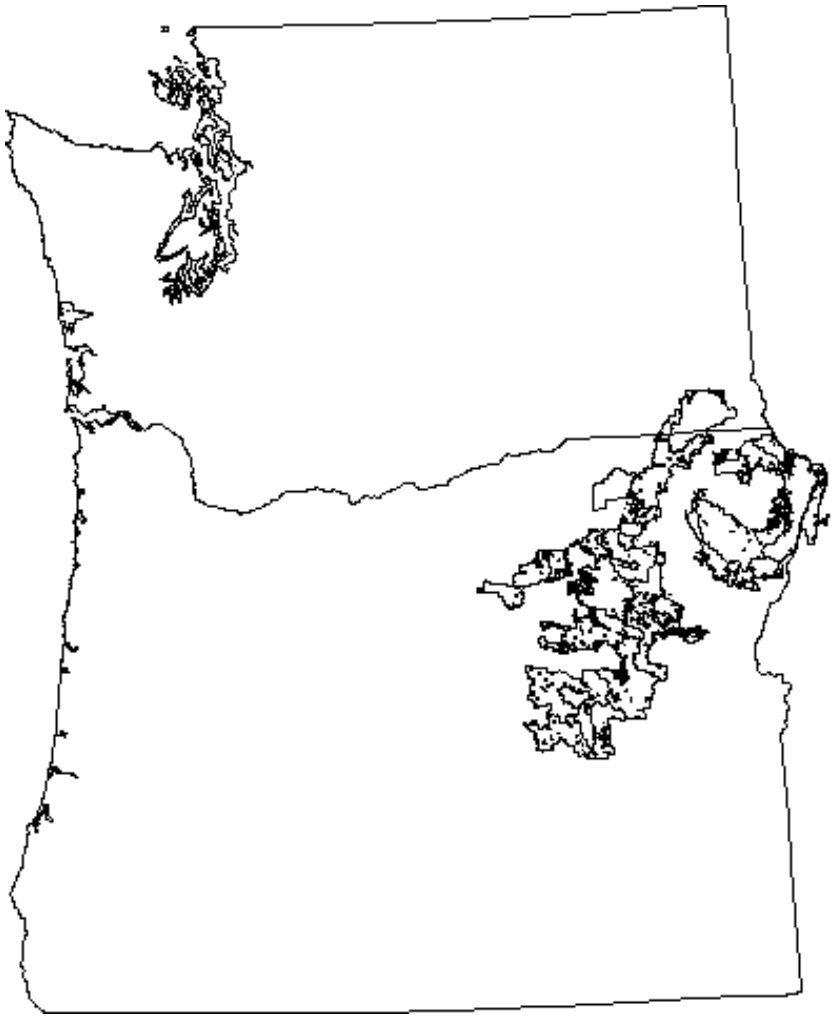

Analyzing Insect and Disease Risks for Watershed Analysis with the UPEST[1] Risk Calculator Program

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Introduction

Watershed analysis is an important and integral part of the analysis of ecosystems. Watershed analysis requires the assessment of physical, hydrologic, biological, social, and economic factors over large areas of the landscape to describe the distribution pattern, types, and relative importance of resource values, altered environmental conditions, and mechanisms of environmental change in watersheds (Anon. 1994).

Because watersheds often cover landscape areas of tens of thousands, and occasionally, hundreds of thousands of acres in size, cost constraints and time factors often preclude acquisition of new data to comprehensively address key questions within watersheds. In most situations, existing data provides enough information to broadly address various resource questions on a watershed basis. Insect and disease risks in a watershed often are

[1]Developed by Alan Ager (Umatilla NF), and Don Scott and Craig Schmitt (Wallowa-Whitman NF).

closely related to interactions of vegetation patterns and conditions, physiography, climatic influences, and disturbance histories. Many of these factors can be analyzed from existing datasets maintained by most National Forests or Ranger Districts, or by other federal resource management agencies.

Several powerful computer-based software tools are presently available as decision support systems to help in watershed or ecosystem analysis (Mowrer 1997). Many different and complex questions can be addressed if corporate data can be readily accessed and structured to use the latest methods of computer-based geographic analysis and landscape visualization technology. Many analyses can easily be done using existing Geographic Information System (GIS) data on a desktop PC with a combination of commercially available computer software and public domain software developed by the U. S. Forest Service and other cooperators.

Insects and Diseases in Watershed Analysis: Development of a Risk Calculator

The evaluation of insect and disease conditions within watersheds is one important component included in recent watersheds analyzed in the Blue Mountains of northeastern Oregon and southeastern Washington. Analysis of insects and diseases in a watershed analysis can take several forms. One approach might be to survey the area of interest to determine the abundance, diversity, and spatial distribution of insects and diseases over the area. Another approach might be to assess the nature and levels of resource damage related to insects and diseases on the watershed, and assess how these levels and damage relate to other resource issues and concerns within the watershed.

While these data are of interest to the resource manager, they require physically visiting the area to conduct surveys to collect appropriate data. This often makes them prohibitively costly and labor intensive for large areas like watersheds. Also, the time-frame needed to conduct these types of field visits is usually restricted due to the established time schedule for completing a typical watershed analysis. Recent aerial insect detection survey maps may be available to provide some of this information, but these surveys cannot detect and map most disease conditions within forest

stands; nor do they necessarily provide information about the susceptibility of the stands other than to indicate the presence or absence, and relative size of insect infestations.

One way to supplement these data is to analyze relative stand risks for insect and disease outbreaks, or potential resource damage, using stand-based information containing risk component variables that already exist in corporate databases. Given the costs and difficulties associated with conducting field surveys, we have found this to be the most cost-effective, and expeditious approach to analyzing a number of insect and disease concerns within large, forested watersheds. To accomplish this type of timely analysis, we designed a computer software program, UPEST, written and compiled in Borland Pascal with output to Paradox tables, to analyze risk component variables contained in a Forest's corporate database as required by different insect and disease models. Our application uses some of the latest landscape visualization and spatial analysis technology (e.g., UTOOLS/ UVIEW[2,3]) to produce and display maps of the pixel-based output from the UPEST insect and disease risk calculator. We designed this DOS-based microcomputer program to provide an efficient, cost-effective means of assigning insect and disease risk indices to forest stands and related resources on entire watersheds and larger forested land bases without having to spend weeks in the field measuring and evaluating stand conditions, and insect and disease populations and damage conditions. Currently, the program is used to calculate risk indices for various damaging insects and diseases in the forests of the Blue Mountains of northeastern Oregon and southeastern Washington using existing vegetation, and spatial databases available in a Forest's existing corporate database, and layers from their GIS system. The UPEST program uses the UTOOLS software to build Paradox input databases. The program can be updated with new models or easily expanded or adapted to other geographic regions with the addition of appropriate insect and disease models, or by changing the risk variables specific for those areas.

The UPEST program improves a resource specialist's ability to identify multiple-factor influences that have caused, or have the potential to cause,

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[2]Ager et al. (1995a).

[3]Ager and McGaughey (1997).

degradation of a watershed. Through Paradox database queries and mapping the query results with UVIEW[4], relative risks of insect and disease outbreaks or related resource damage, along with other disturbance factors and ecosystem processes, can be quickly analyzed and mapped across a watershed. Products of such analyses may be in the form of tabular information (e.g., acres by risk level), or depicted by stratification maps of the watershed based on risk indices generated by the UPEST program.

Insect and disease risk indices displayed in maps can be overlaid with similar risk probabilities for a number of other disturbance factors and events, resource concerns, and watershed deterioration indicators to identify specific areas of concern. For example, one might wish to identify areas that have a combination of highest risk probabilities for mixed conifer root diseases and insect defoliation; highest levels of fuel loading and ladder fuels; greatest damage to stream-side vegetation and potential for stream bank erosion and stream temperature increases; and highest loss of a certain wildlife habitat or cover species. Such areas might then be considered for watershed restoration projects because of the "high" risk-rating for each of the individual analysis components.

In virtually every watershed analysis application to date, the UPEST risk analysis has been an integral component in the evaluation of vegetation sustainability. The insect and disease risk determined by UPEST analysis has been correlated with vegetation condition, fire risk, wildlife habitat condition, and various other key issues on most of the watersheds analyzed in the Blue Mountains.

UPEST Risk-Rating Models and Rationale

Risk-rating methods and models can be designed in various ways. Our first choice--and clearly the easiest--was to employ models that were already available, rather than develop new ones. Discovering the methods presently available to evaluate stand risk for insect attack or insect-caused damage across broad landscapes was fairly straightforward. Nearly all major forest insects occurring in the Blue Mountains have been previously addressed in the literature by some form of risk-rating or hazard-rating model. We have selected risk models for seven different damaging insects

[4]UVIEW is a landscape visualization module within the UTOOLS program.

to include in the UPEST program. The insect risk models used in UPEST are shown in Table 1. Sometimes more than one descriptive model has been included for a particular insect (e.g., mountain pine beetle). Each model is different because of varying environmental, biological, ecological, and biometrical factors and components involved in determining the relative risk for a particular insect species. In some cases, model components for a particular insect may vary by host plant, as well (e.g., mountain pine beetle in ponderosa pine verses lodgepole pine). Some models have been developed and tested using actual stand data from the Blue Mountains (cf., Heller and Kessler 1985; Heller and Sader 1980; Scott and Schmitt 1998; and Ulliman and Kessler 1985), while others have been developed elsewhere in the West but have general applicability in the Blue Mountains physiographic province, as well as in other regions of the West.

Insect Species	**Reference**
Mountain Pine Beetle Risk (lodgepole pine)	Shore and Safranyik (1992)
Mountain Pine Beetle Susceptibility Index (lodgepole pine)	Shore and Safranyik (1992)
Mountain Pine Beetle Pressure Index (lodgepole pine)	Shore and Safranyik (1992)
Mountain Pine Beetle Risk (lodgepole pine)	Amman et al. (1977)
Mountain Pine Beetle Risk (ponderosa pine)	Stevens et al. (1980)
Mountain Pine Beetle Risk (ponderosa pine)	Schmid et al. (1994)
Douglas-fir Beetle Risk	Weatherby and Thier (1993)
Spruce Beetle Risk	Schmid and Frye (1976)
Fir Engraver Risk	Schenk et al. (1977)
Douglas-fir Tussock Moth Risk	Heller and Sader (1980)
Western Spruce Budworm Risk	Ulliman and Kessler (1983)

Table 1. Insect species and author references to models included in the UPEST program.

Certain of the insect risk models have several components that are calculated by UPEST. The mountain pine beetle risk model for lodgepole pine by Shore and Safranyik (1992), for example, has indices of "susceptibility" and "pressure" computed by the UPEST program, in addition to "risk." These indices are components used in the computation of risk by this model. We felt it would ease interpretation and understanding of these indices' influence on the computation of risk if these components were generated and displayed along with the component of risk. The variables used by each of the insect models are described in Operations Manual for UPEST which is distributed along with the software (Ager 1996). Forest disease models that calculate and describe levels of stand risk to diseases were, for the most part, unavailable in the literature. Those used in UPEST were developed by one of the authors (Schmitt). These models are based on professionally accepted risk components or parameters that have been observed and published in the literature. Our review of literature revealed that there were few past efforts by others to develop models to estimate risks or hazards of stands to forest diseases. We used various stand structural information, site and biotic factors, plant community type information, harvest histories, successional stages, and other environmental factors to develop the disease risk models. The data required by these models comes from the Forest vegetation database and GIS layers.

Table 2 contains a list of the seven disease models included in UPEST. The variables used by each of the disease models are described in Operations Manual for UPEST (Ager 1996). A description of the individual disease models, and a discussion of the risks calculated in UPEST is given in Scott and Schmitt (1998).

Forest Disease	**Reference**
Douglas-fir Dwarf Mistletoe Risk	Schmitt (1994)
Ponderosa Pine Dwarf Mistletoe Risk	Schmitt (1994)

Western Larch Dwarf Mistletoe Risk	Schmitt (1994)
Mixed Conifer Root Disease Risk	Schmitt (1994)
Tomentosus Root and Butt Rot Risk	Schmitt (1994)
Schweinitzii Root and Butt Rot Risk	Schmitt (1994)
Indian Pain Fungus Risk	Schmitt (1994)

Table 2. Forest diseases and author references to models included in the UPEST program.

Each of the 14 insect and disease models in the UPEST Risk Calculator uses methodologies described by the various authors of the models (see Ager et al. 1995a). Obviously, with this number of models by different authors there are bound to be a similar number of differing definitions of "risk." To simplify the possible confusion over different authors' definitions of risk or how it is classified, we combined a few definitions to produce a single, generalized one that we felt could reasonable define risk as produced by the UPEST Risk Calculator program. Hence, our definition of "risk" in regard to forest insects and diseases generally refers to the ***expectation*** of levels of tree mortality or damage from insects or diseases within a specified period of time, that will interfere with management of resources associated with forested landscapes (adapted from Gast et al. 1991, and Shore and Safranyik 1992). Risk-rating models for important forest insects and diseases in the Blue Mountains that have been incorporated into the current version of UPEST include bark beetles, defoliating insects, dwarf mistletoes, root diseases, and a stem decay. This is a starting point; as more models are developed for other insects and diseases, they may be included in the UPEST program, as well.

Risk-rating Limitations, Assumptions, and Validation

The UPEST risk-rating calculator has been designed to use stand attribute data obtained by either stand examinations or aerial photo interpretation.

There has been limited field verification of the accuracy of risk indices produced by UPEST. Field verification of current or potential insect and disease incidence or severity information during an insect and disease risk analysis is not always possible because of the limited time available to prepare a watershed analysis report. Field verification is certainly desirable in view of the risk of drawing wrong conclusions from an analysis, though the probability of this may be low, at least when input data are of very recent origin. A current study is presently underway to field-validate the insect and disease risks generated in a recent UPEST risk analysis to support a watershed analysis on the Umatilla National Forest, Pacific Northwest Region. Results of that study are forthcoming, and will provide a level of confidence that can be expected from future UPEST analyses.

We have built into UPEST some computational formulae and algorithms that utilize a set of assumptions and rule bases to calculate certain model components that may be missing in the original databases containing the input data. UPEST uses a specific set of database fields to calculate risk indices for each insect and disease model. If the data are not complete for running a particular model, UPEST will attempt to estimate the missing parameter required by the model. In the process of estimating missing stand metrics, UPEST searches for the "best" data according to the priorities in Table 3. For example, if height is missing and diameter breast height (DBH) is present, then the latter will be used with a lookup table to estimate height. If both height and DBH are missing and size class is present, then the latter will be used to estimate height.

Variable	**Estimated From:**
Height	DBH or Size Class
DBH	Height or Size Class
Crown Diameter	DBH or Size Class
Age	DBH or Size Class
Trees per Acre (TPA)	Crown Diameter and Canopy Closure
Basal Area per Acre (BA)	TPA and DBH

Table 3. UPEST model variable and alternate variables used to estimate model variable when model variable is missing from a pixel and required by an individual insect or disease model.

Clearly, some of the methods for estimating missing stand parameters are coarse at best. Recognition of this fact is important when interpreting the results. Certainly, one might reasonably question the accuracy of an analysis based on a dataset that contained many estimated stand metrics. The current version of UPEST, however, does not provide any means of tracking estimated parameters. This may be a feature added to future upgrades of the program, that some will find useful.

If the data are not complete for a particular model and cannot be estimated from other data, as in the above, the program outputs a -99 for that pixel/pest model combination. Thus, databases can contain missing data and not affect program operation, except that some risk models may not be calculated for certain pixels. In this case, there will be a portion of the watershed containing a measure of risk for insects or diseases that will not be evaluated due to pixels with inestimable missing parameters. We have found that for most watersheds we have analyzed, these pixels will vary by watershed and by insect or disease model.

In some cases, the total acreage of the combined risk categories for an insect or disease is less than the total acreage of the watershed. This is the result of missing or fragmentary data which prohibits running that risk model on those pixels that contain missing data for one or more model components. Thus, the mapped and reported acreage from a UPEST risk analysis generally includes only those pixels that contain complete data. Data for private or other ownerships within watersheds are often lacking. These areas typically show up as "holes" in a risk map, even though they may contain some component of insect or disease risk. These risks cannot be analyzed without the data.

Table 4 shows the average percent of the watershed area with missing data for each insect and disease model on 14 different watersheds analyzed by UPEST. On average, our experience has shown that less than a third of a watershed will contain missing data that either cannot be estimated, or are unavailable for analysis due to pixels associated with private and other lands, based on our data. The models for the Douglas-fir beetle and the Douglas-fir tussock moth had the most consistency for fewest missing data components; or at least those that could not be estimated by other means.

In general, the insect models are quite different from one another, both computationally, and in their required input parameters. This accounts for some of the variations between the insect models in percent of watershed with missing data in table 4 . Any given pixel may contain all, or an estimable portion of the components for one model. A different model may contain some missing components that prevent the model from executing when those components cannot be estimated. Therefore, one model may compute a risk for the pixel, while the other model may not. The disease models are more similar to one another computationally and in required input parameters than the insect models, so there is less variation between disease models shown in the analysis of percent of watershed with missing data (table 4), than for the insect models.

Insect or Disease Model	**No. Watersheds Analyzed**	**Average Percent of Watershed With Missing Data (Mean ± SE)**
Mountain Pine Beetle Risk (lodgepole pine)	14	30.3 ± 10.19
Mountain Pine Beetle Risk (ponderosa pine)	14	25.5 ± 7.22
Douglas-fir Beetle Risk	14	9.9 ± 5.50
Spruce Beetle Risk	14	31.3 ± 7.02
Fir Engraver Risk	14	12.8 ± 7.81
Douglas-fir Tussock Moth Risk	14	4.3 ± 4.06
Western Spruce Budworm Risk	14	12.3 ± 6.28
Douglas-fir Dwarf Mistletoe Risk	14	34.8 ± 7.11
Ponderosa Pine Dwarf Mistletoe Risk	14	31.3 ± 6.54
Western Larch Dwarf Mistletoe Risk	14	31.5 ± 6.53

Mixed Conifer Root Disease Risk	14	32.2 ± 6.65
Tomentosus Root and Butt Rot Risk	14	31.5 ± 6.54
Schweinitzii Root and Butt Rot Risk	14	31.5 ± 6.54
Indian Pain Fungus Risk	14	31.5 ± 6.53

Table 4. Average percent of watershed with missing and inestimable data parameters, by insect or disease model.

The possibility of incorrectly evaluating insect and disease conditions because of outdated input information, or because of data input errors, is a problem that must be kept in mind when using UPEST. It is always prudent to state any assumptions made, and any known or possible risks of error when making an analysis with the UPEST program. Misinterpretation of the actual risk-ratings obtained from UPEST models could also result in an incorrect evaluation of insect and disease conditions if one was not familiar with the particular model, or the author's intended interpretation of the risk indices generated by the model. This is one of the reasons why we suggest that an entomologist or pathologist be involved in the interpretation of risk-rating results.

We tried to take that into account, and to a certain extent simplify the interpretation of risk, when we designed the "risk levels" or "risk categories" generated by UPEST, based on individual model results. The published models employed one of three types of rating system (for more detailed discussion of the different systems, see Ager 1996). These different rating systems made interpretation and comparison of results difficult and confusing. We sought to simplify this for all the models by standardizing the various types of rating system into a system with only three rating classes: 1 (=low), 2 (=moderate), and 3 (=high). Certain of the models contained a 0 (zero) output rating class for instances when there was no host vegetation present. Other models were not designed to be computed without a host (e.g., a division by 0 would result). For these models, any pixel with a no-host situation was assigned to the "low" risk class. By doing so, we extended the definition of low risk to also include "no-risk" areas. This is an artificial construct that we decided was necessary to limit the risk indices returned by the UPEST program to only 3 classes. Furthermore, in any application of UPEST it is important to remember that insect and disease ratings generated by UPEST are standardized in such a manner so as to

produce indices of the relative likelihood of risk of occurrence and severity, rather than a portrayal of actual on-the-ground conditions. At the project or stand level, it is imperative, then, to use actual occurrence and severity information along with risk probabilities to design stand treatment prescriptions. UPEST-generated risk-ratings will be of most use in determining areas likely to experience insect and disease effects, and in estimating broad-scale forest health conditions.

It is important to note that UPEST is an experimental insect and disease risk calculator that uses some models which have not been validated for the Blue and Wallowa Mountains. In order to run several of the models with photointerpreted data, it was first necessary to make certain assumptions to relate photointerpreted data to stand-based data, and then compute the model variables (see Ager et al. 1995b for a list of model variables and methods for estimating certain model components).

To reinforce statements on the accuracy of UPEST made earlier, we offer one final caveat regarding the risk indices. Although the models are correctly computing risk as the authors intended, accuracy of results is ultimately determined by the quality and vintage of the input data. Since some of the data from a Forest's corporate database may be from stand exams taken as long as a decade ago, actual vegetation condition, species composition, and other stand components and parameters used by the models may have changed over time. Older datasets that have not been updated since the original stand exam could lead to different risk indices when compared to analyses conducted using more recently acquired data. For example, a risk-rating computed for an insect on an area where a recent fire or harvest occurred, using recently acquired data, would be entirely different than a risk-rating for the same insect, on the same area following the fire or harvest, using pre-fire or -harvest data. For this reason it is imperative that one knows the vintage of the data that is being used in an analysis conducted by UPEST. Clearly, it is best to use only the most recent data in an analysis. If the datasets are very old, it is probably better to avoid using them, rather than to risk producing an inaccurate risk-rating analysis with UPEST.

Interpreting Risk Indices

By standardizing the format for reporting and mapping the risk-ratings calculated by UPEST into three levels (low, medium, and high), we intended

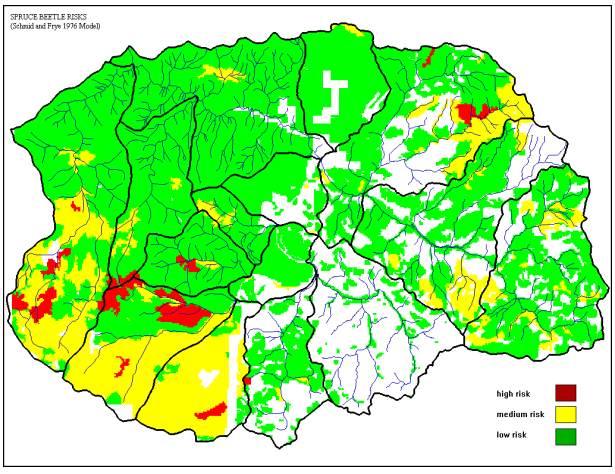
for these to be viewed only in relative terms. That is, the demarcations between high and medium, and medium and low are artificial, and there is only a relative likelihood of a given insect or disease being more active in the higher risk rating. However, when using UPEST to calculate insect and disease risks in a watershed analysis, we recommend that most attention be given to those subwatersheds that are identified as having high and medium ratings for **multiple** insects and diseases, since these common ratings for several insects and diseases are probably pointing out some serious stand problems based on relative risks. Obviously, if an area has medium or high risks for several different insects and diseases, one ought to have greater concern for the health and sustainability of that particular area.

Differences in methodology used in calculating different risk indices dictate that some care be exercised in interpreting the meaning of these indices. To fully understand the risk indices one needs to be familiar with each of the models used to calculate the indices. We advise a thorough reading and understanding of the supporting literature, and the UPEST Operations Manual (Ager 1996) for each model before using the model, or attempting an interpretation of the model outputs. For example, in the case of bark beetle risks, a "high" rating generally means that current vegetation, and physiographic conditions are such that there is a high likelihood that serious stand damage (i.e., tree mortality) **could** occur in the event of insect population increase to outbreak. Interpretation of risk indices for defoliators, on the other hand, is slightly different, and depends on which defoliator is being rated. For instance, a "high" rating for Douglas-fir tussock moth means that there is a greater than 60-percent probability that a subwatershed would be defoliated by tussock moth in the event of an outbreak; whereas, a "high" rating for western spruce budworm means that stands within the subwatershed are expected to incur greater than 50-percent defoliation during the course of a budworm outbreak. Ratings of "low" for both insects and diseases generally mean that host, site, past management, and other conditions are not suited for development of insect or disease epidemics. It does not necessarily mean that there is **no** level of insect or disease activity present in stands, although this may be the case, especially where stands are composed of non-host species. It should also be remembered that unless otherwise specified, stands that are composed of non-host species, or that are unforested altogether, are included in the "low" risk category for both insects and diseases by the models. Thus, low risk means both "**low**" and "**no**" risk in these cases.

Individual Verses Composite Risk-Ratings

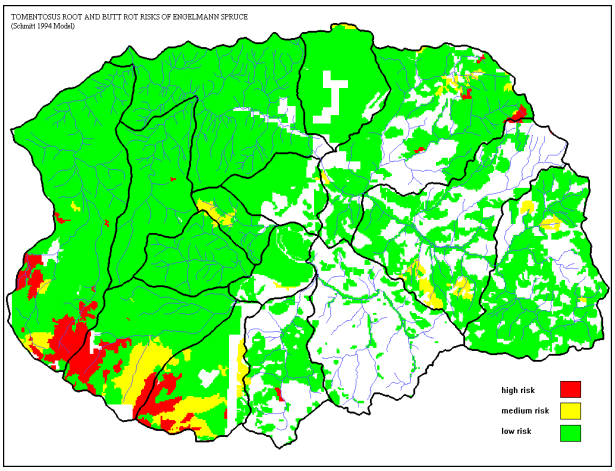
The UPEST program has been designed to provide risk ratings for individual insects and diseases rather than a composite rating for all insects and diseases analyzed on a watershed by UPEST. This is partially because different management objectives would allow different weights to be applied to different components of a composite score. That is, those insects and diseases that result in conifer mortality would be considered differently from those insects and diseases that cause growth reduction and stem decay, depending upon the management allocation. However, it is possible to design queries in the UVIEW landscape visualization program to identify composite risks for any combinations of insects and diseases.

Landscape visualization is a useful process in depicting and evaluating UPEST analysis results in a watershed analysis. The most basic use of UPEST is to produce individual colored-map displays of the risk indices for each insect and disease by constructing and displaying queries for an individual insect or disease in UVIEW from the data output in the UPEST Paradox table. For instance, such a map was generated by querying the UPEST output database for the spruce beetle (*Dendroctonus rufipennis*), and mapping the query

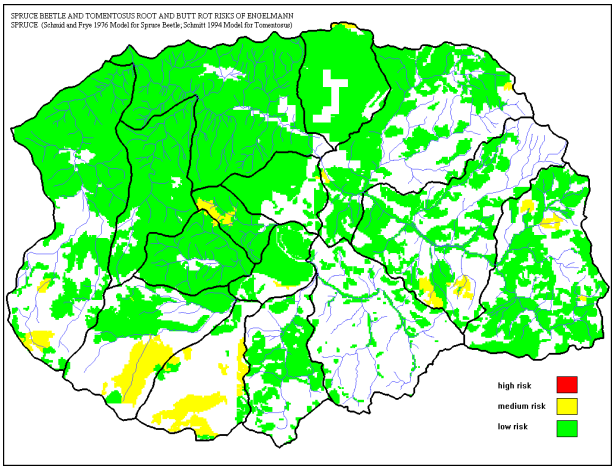


with UVIEW in figure 1. Similarly, figure 2 displays the UVIEW-mapped query of the UPEST output database to generate a risk map for the disease of Engelmann spruce, Tomentosus root and butt rot (*Inonotus tomentosus*). The UVIEW queries can also be constructed to display combinations of risks for more than one insect or disease. To illustrate this we have designed a

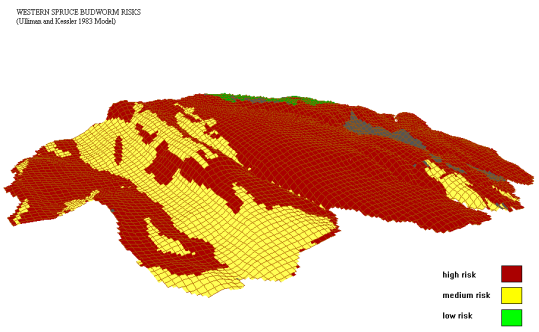
query to map out the areas of similar risk for both spruce beetle and tomentosus root and butt rot within the Granite Creek Watershed, Wallowa-Whitman National Forest (fig. 3). The map shows only those areas of the watershed that have risk indices of low, moderate, and high for both the insect and the disease (compare fig. 3 with figs. 1 and 2). This kind of a combination map opens up other possibilities for stratifying and overlaying information from a watershed analysis, as we have alluded to previously.



The UVIEW program allows mapping in either a two-dimensional view (Plan View) or a three-dimensional view (Terrain View). We prefer mapping out UPEST risks in the Plan View rather than the Terrain View because it is easier to see all the risks that occur in the watershed. The Terrain View uses a digital terrain model to map or display elevation contours to produce perspective views of the data from the terrain model. The Terrain View provides a capability to adjust the positioning of the head, or "eye," the location and focus, or the target location of the displayed map. However, we find that the Terrain View often obscures risk indices that are mapped on the back-side of the terrain being viewed. The risk information available to the viewer is more limited in this Terrain View, than in the Plan View. Figure 4 is an example of western spruce budworm (*Choristoneura occidentalis*) risks mapped in the Terrain View. This view depicts risk condition as these patterns might appear on the actual landscape. Many other types of spatial analysis are possible with the UVIEW program. We make use of only the most basic capabilities of UVIEW for insect and disease risk analysis, as that serves our purposes of spatially depicting insect and disease risks over the entire watershed.


SPRUCE BEETLE AND TOMENTOSUS ROOT AND BUTT ROT RISKS OF ENGELMANN SPRUCE (Schmid and Frye 1976 Model for Spruce Beetle, Schmitt 1994 Model for Tomentosus)
high risk
medium risk
low risk

The UVIEW program offers a number of options for viewing terrain models. The view of the image can be easily changed by features in the program that allow the user to adjust the position of the view point up or down, or from either side of the image to achieve a different perspective of the terrain. The focus can also be changed to a position closer to, or further away from, the terrain. In addition the distance perspective can be changed by zooming in or out on the terrain. Moreover, scripts can be used to produce a sequence of terrain images to show the landscape from different viewpoints, that simulate "flying over" the terrain. These features are useful to visualize the patterns of insect and disease risk indices across the landscape when viewing the terrain model in this three-dimensional mode. For a more complete discussion of the UVIEW program, see Ager and McGaughey (1997)



Summary

There has long been interest in rating forest stands for insect and disease risks. Entomologists took an early lead in developing several risk- or hazard-rating systems for a number of forest-damaging insects. Risk-rating models for most forest pathogens are rare by comparison, although most of the parameters of disease risk have been known in varying degrees for some time.

While several systems have now been developed recently by forest insect and disease management specialists in the western U.S. (see for example, Steele et al. 1996), to our knowledge, the UPEST program, used in conjunction with UVIEW, is the most comprehensive risk-rating system for individual insects and diseases on a watershed or landscape basis. With the UPEST program, insect and disease risk analysis can now be integrated with other watershed analysis parameters through database links and Paradox database queries. UPEST, when used in conjunction with the UVIEW module in UTOOLS, can provide very precise map displays of insect and disease risk levels across a watershed at about 2.5-acre pixel resolution. Moreover, queries can be structured within the database query facility of UVIEW such that the UPEST-generated insect and disease risks can be overlaid with other watershed resource risks to pinpoint problem areas. Custom designing these queries to analyze various combinations of watershed resource risks are limited only by one's imagination.

Although UPEST can provide a very powerful analysis of insect and disease risks, which can be further analyzed with multiple watershed resource risk indices, data vintage becomes a major limiting factor in the accuracy of the analyses. Efforts should be made to ensure that the data used by UPEST are as recent as possible. In addition, mixed ownerships are difficult to analyze accurately because data for ownerships other than Forest Service are typically not included in the corporate database. Aerial photo-interpretation may provide missing data where photo coverage is available.

Overall, UPEST analysis of insect and disease risks provides an efficient and inexpensive means of providing valuable biological information for watershed analyses. It enhances the usefulness of these analyses by the resource manager. Future enhancements and addition of new insect and disease models will extend the usefulness of the UPEST program for watershed analysis and many other types of ecosystem analyses. We believe that UPEST analysis of insect and disease risks will be of major importance to such future tasks as revising and reissuing the Forest Land and Resource Management Plans, as well as in tracking departures from Historic Range of Variability (HRV) for insects and diseases.

Plans are underway to rewrite the program to run under Microsoft Windows 95. It will also be revised to analyze data on a stand basis rather than on a pixel basis, in the future. These enhancements will make the program much more "user-friendly," and undoubtedly, will significantly increase its use among pest management specialists and resource managers. Changing from a pixel-based program to one that is stand-based will make the preparation of

input databases much easier, also. This alone will be a welcomed improvement to those who have struggled with preparing these input databases in the past.

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